RADIOLOGICAL AND CHEMICAL TECHNICAL SUPPORT CENTER

HUNTERS POINT ANNEX - Parcel B

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ABSTRACT

Three soil samples from the Hunter's Point Annex, Parcel B, were received at the National Air and Radiation Environmental Laboratory (NAREL) for examination to determine the radionuclide content of the samples, the particle-size and radionuclide distribution, and to perform a preliminary petrographic examination, including heavy-mineral separation. The primary objective of this study was to determine the type and nature of radionuclides in the soil samples and the likely source of these radionuclides.

The following conclusions are based on the results of this study:

1. The particle-size distributions of Soil 1, 2, and 3 are very similar (Table 1-1 and Figure 4-1). Approximately half the material is in the -16/+200-mesh (-1.19/+0.074-mm) fractions. Much of the remaining material is in the -400-mesh size range (<0.038-mm). Only a small percentage is found in the +16-mesh (>1.19-mm) fractions.

2. Each whole soil sample contains only background quantities of uranium, thorium, and radium (Table 2 -1). The radionuclide distribution in the soil fractions analyzed are typical, with less than 2.5 pCi/g of any isotope of uranium, thorium, and radium.

3. The naturally occurring radionuclides measured in the uranium-238 chain, namely uranium-238, thorium-230, and radium-226, are in equilibrium, indicating that no radionuclide has been enriched or depleted by either artificial or natural means (Table 4-1 and Figure 4-2). The same comments can be made for the naturally occurring radionuclides measured in the thorium-232 chain, namely, thorium-232, radium-228, and thorium-228 (Table 4-2 and Figure 4-3). Considering the nature and concentrations of these radionuclides and their decay products, these results indicate that these radionuclides are due to natural causes.

4. Petrographic examination of the minerals in the three soil samples indicates that the radioactivity is from naturally occurring monazite and zircon (Tables 3-1 and 3-2). Very minor amounts may be associated with cinder/slag materials.

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1.0 Introduction

Naval Station Treasure Island, Hunter's Point Annex (formerly the Hunter's Point Naval Shipyard) consists of 965 acres of the Hunter's Point peninsula on San Francisco Bay (DEA94). After World War II, the Naval Radiological Defense Laboratory (NRDL) used the area to decontaminate and dispose of ships that participated in nuclear weapons tests at the Bikini Atoll. The NRDL also conducted numerous radiological studies during that the. In 1991, elevated gamma activity was discovered in one landfill, in Parcel E, along the southern shoreline of the peninsula. The source of contamination was attributed to luminous radium dials, metallic discs (buttons) approximately 1 to 1-1/2 inch in diameter, glass beads approximately 1/2 inch in diameter, and possibly small flakes of oxidation products from the weathered discs and fine-grain glass material from crushed beads. The total volume of contaminated soil is estimated to be between 40,000 and 120,000 yd^3. Although contamination may be, in many cases, essentially point sources within that volume.

Three soil samples from the Parcel B area, northeast of Parcel E, were sent to the National Air and Radiation Environmental Laboratory (NAREL) for examination to determine if the radionuclide activity in that area is from a natural source and if the activity is sufficiently low to permit unrestricted removal and use of soil. NAREL was asked to perform radionuclide analyses, particle-size and radionuclide distribution analyses, and petrographic studies of select soil fractions in an attempt to make these determinations. This report presents the results of those analyses and studies.

2.0 Experimental

2.1 Sample Preparation

NAREL received three 3-kg soil samples for this study. The samples were initially screened for gross beta/gamma activity using a Geiger/Muller tube. After initial screening, each sample was weighed, dried at 60°C, reweighed, thoroughly mixed, and then split into homogenous 400-mL aliquots. One aliquot from each of the three soil samples was then analyzed by gamma spectrometry (see Section 2.6.1). A 50-g aliquot was removed to be analyzed for uranium, thorium, plutonium, and radium (see Section 2.6.2) and gross alpha/beta counting (see Section 2.6.3).

2.2 Vigorous Wash

Before sieving, each 400-mL aliquot of whole soil was vigorously washed in water for 30 min at a rotational velocity of 350 rpm and a liquid-to-solid ratio of 4mL/1g (SCA91a). The vigorous washing process liberates smaller particles from larger particles and reduces the size of colloidal material.

2.3 Wet Sieving

After vigorous washing, the soil sample was fractionated according to size using ASTM standard sieves (SCA91b). The aliquots were separated into size fractions at 6.35 mm (¼ in), 1.19 mm (16 mesh), 0.25 mm (60 mesh), 0.074 mm (200 mesh), 0.038 (400 mesh). The resulting fractions were dried at 60°C and weighed. The -¼/+16 and -16/+60 fraction were combined to produce a single -¼/+60 fraction; similarly, the -60/+200 and -200/+400 fractions were combined to produce a single -60/+400 fraction. The combined fractions, +¼-in, and the -400-mesh fractions were analyzed by gamma spectrometry. The combined fractions and the -400-mesh fractions were also analyzed for uranium, thorium, plutonium, and radium.

2.4 Petrographic Examination

A petrographic examination was performed on each whole soil sample. Fractions produced by wet sieving were further separated by hand sieving to produce six to seven size fractions (see Table 3-1 for the actual fractions). Each size fraction was examined, starting with the visual examination of the coarser size fractions. The finer sand and silt fractions were examined by means of petrographic and binocular microscopes, and photomicrographs were taken of significant features. Where available, at least 100 particles were counted to provide a statistical point count on each size fraction.

In order to provide a more quantitative assessment of the heavy mineral fraction, which frequently contains the more abundant collection of radioactive minerals, these particles were separated from the bulk material of the fractions by the sink float method, using sodium polytungstate with a density of 2.89 g/cc (CAL87). Representative 5-g samples of the -60/+100, -100/+200 , and -200/+400 mesh-size fractions were separated, the magnetic fraction was removed by a hand-held magnetic, and the remaining heavy minerals were examined with the petrographic microscope. Based on the quantities of heavy-mineral present in the separated fractions, the three fractions for Soil 1 were combined into a single -60/+400 fraction, the same fractions for Soil 3 were similarly combined. For Soil 2, the -60/+100 and -100/+200 fractions were combined into a -60/+200 fraction, producing two fractions, -60/+200 and -200/+400 for Soil 2. These heavy-mineral fractions were analyzed by alpha spectrometry for uranium, thorium, and plutonium and for radium by the deemanation method.

2.5 Wash Water

Water from the vigorous wash and sieving procedure for each sample was collected and a Percol 788N flocculant was added to settle suspended solids and then was filtered under pressure through a 0.025-mm paper filter. A representative sample of the filtered wash-water from each soil sample was analyzed for radioactivity by gamma spectrometry prior to discharge.

2.6 Radionuclide Analysis

2.6.1 Gamma Spectroscopy

An aliquot of each whole soil, particle-size fraction, and wash water were analyzed for gamma emitting radionuclides by counting for 1000 min on high-purity germanium detectors (EPA80a).

2.6.2 Gross Alpha/Beta Analysis

The soil samples were ashed and solubilized in hot acid mixtures, and an aliquot was evaporated on a planchet for counting by a low-background gas proportional counter (EPA80b).

2.6.3 Actinide Analysis

Aliquots of each whole soil sample were ground so that the sample would pass through a 16-mesh sieve. These whole-soil aliquots, particle size fractions, and heavy-mineral fractions were solubilized in hot acid mixtures. Uranium and plutonium were extracted from the mixture, selectively coprecipitated with lanthanum fluoride carrier, and analyzed by alpha spectrometry (EPA84a). Thorium was separated by ion-exchange chromatography, coprecipitated with lanthanum fluoride carrier, and analyzed by alpha spectrometry (EPA84b).

2.6.4 Radium Analysis

An aliquot of each whole soil and particle-size fraction was analyzed by NAREL personnel for radium-226 by deemanation (EPA84c) and radium-228 by coprecipitation with barium sulfate and beta counting (EPA84d).

3.0 Results

3.1 Particle-Size Distributions

Three soil samples (Soil 1, Soil 2, and Soil 3) from the Hunter's Point Annex, Parcel B were each vigorously washed and wet sieved using a nest of five sieves, ¼ in, 16 mesh, 60 mesh, 200 mesh, and 400 mesh, to determine their particle-size distribution. The results of those procedures are presented in Table 1-1 in Appendix A.

3.2 Radionuclide Distributions

An aliquot of each soil fraction from particle sizing as well as each whole soil was analyzed by alpha spectrometry for uranium, thorium, plutonium, and radium radionuclides. Radium-226 was also analyzed by deemanation. The whole soils were analyzed for gross alpha and beta activity to determine these levels of activity before analysis by alpha spectrometry. A similar aliquot of each whole soil and particle-size fraction was also analyzed by gamma spectrometry. The results of these analyses for uranium, thorium, and radium are presented in Table 2-1. The radium-226 values are from deemanation analysis while those of radium-228 are from gamma spectroscopic analysis.

3.3 Petrographic Examination

A petrographic examination was performed on each soil sample. Each size fraction was examined, and a statistical count was taken. The statistical results of these examinations are presented in Table 3-1 in Appendix A. Each category is described below, starting with the materials in the coarser fractions.

Serpentinite

Greenish grey to light greenish grey, soft, moderately weathered, subangular to subrounded serpentinite comprises 35 to 65 percent of the coarse sand and gravel fractions (+100-mesh; >0.13-mm) of Soil Sample 1 and is a minor occurrence in the highly weathered rock particles of Soil Samples 2 and 3 (Table 3-1). Some of the serpentinite contains local parallel bands/veins of asbestos (chrysotile). A photomicrograph of a band of asbestos in a gravel-size particle of serpentinite is depicted in Plate A. This is the source of asbestos particles that occur as homogeneous particles in sand size fractions (Plate B). The occurrence of the asbestos is mentioned since it, although nonradioactive, constitutes a material hazardous to health.

Highly Weathered Rock

Highly weathered, soft, light grey to tan colored, subrounded to subangular particles of predominantly clay/rock composition comprise from 1 to 20 percent of coarse sand to gravel sized particles of Soil Samples 2 and 3 (Table 3-1). The rock particles are friable and are easily crushed under applied pressure. The composition is predominantly kaolinite clay with minor quartz and biotite. Minor soft serpentinite particles are included in this category.

Granitic Rock Particles

Light grey, medium grained, slight to moderately weathered, subrounded to subangular granitic rock particles comprise 40 to 80 percent of the coarse sand-size and gravel-size fractions (Table 3-1). Mineral composition averages 70 percent feldspar, 20 percent quartz, and 10 percent biotite and magnetite.

Sandstone

Tan colored, rounded to subrounded, friable sandstone particles occur in the medium to coarse sand-size fractions of all three soil samples (Table 3-1). These particles range from trace amounts to 20 percent of these fractions, but their quantity is minor with respect to the total sample. Mineral composition is predominantly quartz in a limonotic/clay matrix. A typical sandstone particle is depicted in Plate A, which shows the abundant clayey matrix and rounded quartz clasts.

Quartzite

White to pink colored, hard, dense, subangular quartzite particles occur in minor amounts in coarse sand-size and in finer fractions in all three samples (Table 3-1). These particles comprise from 2 to 5 percent of the fractions and consist of metamorphosed quartz particles.

Quartz

White to tan colored, hard, dense, subrounded to subangular quartz particles constitute the most abundant mineral composition of the soil in the medium sand to medium silt-size fractions (-60/+200-mesh) (Table 3-1). The quartz content of these fractions ranges from 31 to 74 percent. The vigorously washed particles are clean, durable, and free of radioactivity.

Feldspar

Grey to tan colored, slight to moderately weathered, subangular to tabular shaped feldspar particles occur in amounts ranging from 10 to 20 percent of the medium sand to medium silt-size fractions (Table 3-1). Mineral composition is essentially similar amounts of K-feldspar and plagioclase feldspar. The particles are generally hard and durable with a density similar to quartz and free of radioactivity.

In order to provide a more quantitative assessment of the heavy mineral fraction, these particles were separated from the bulk material of the fractions by the sink/float method and examined with the petrographic microscope. These heavy-mineral fractions were analyzed by alpha spectrometry for uranium, thorium, plutonium, and radium. The results of these examinations are presented in Table 3-2 in the Appendix.

Heavy Minerals

Heavy minerals (greater than 2.89 specific gravity) are hard, dense, durable materials of generally equidimensional particle shape that occur in greatest abundance in the -100/+400-mesh fractions (Table 3-1). The percent distribution in these size fractions ranges from 6 to 47 percent, and the radioactive materials are contained in these heavy mineral fractions. The weight percentages, shown in Table 3-2, are based on a sink-float separation in which sodium polytungstate (2.89 specific gravity) was used to effect a heavy-liquid separation on representative 5-g samples. The percent of respective heavy mineral species was made by statistical point count in oil immersion mounts under a petrographic microscope after first removing the magnetic fraction with a hand magnet. The heavy mineral species are predominantly opaque materials, hornblende, hypersthene, epidote, garnet, monazite, zircon, and minor tourmaline, rutile, and others in trace amounts (Table 3-2).

Radioactive Minerals

The radioactive minerals are monazite and zircon, depicted in Plates C through H, along with other heavy minerals. The percentage distribution of the radioactive minerals is listed in Table 3-2. The monazite occurs most abundantly in the coarser sand-size fractions and zircon in most abundance in the finer sand-size fractions (Table 3-2).

Asbestos

Asbestos (chrysotile) occurs in coarse particles of serpentinite in Soil Sample 1 (Plate A) and in some of the highly weathered rock particle that occur in very minor amounts in Soil Samples 2 and 3. Asbestos occurs as homogeneous, discrete particles in sand-size fractions of Soil Sample 1 (Plate B) in amounts averaging approximately 1 percent and in trace amounts in the sand fractions of Soil Samples 2 and 3 (Table 3-1).

Other Materials

Other miscellaneous materials consist of wood/plant materials, cinder/slag, minor glass, and anthropogenic materials. As shown in Table 3-1, these materials occur in the gravel or course sand fractions. Trace anthropogenic materials are depicted in the photomicrographs (Plate I).

4.0 Discussion

4.1 Particle-Size Distributions

The particle-size distributions of Soil 1, 2, and 3 are very similar (Table 1-1 and Figure 4-1). The particle size of approximately half the material is in the -16/+200-mesh (-1.19/+0.074-mm) fraction. Much of the remaining material is in the -400-mesh size range (<0.038-mm). Only a small percentage is found in the +16-mesh fractions (<1.19-mm).

4.2 Radionuclide Distributions

The radionuclide analyses by alpha spectrometry of Soils 1, 2, and 3, like the particle-size distributions, are very similar (Table 2-1 and Figure 4-2 and 4-3). Each whole soil sample contains only background quantities of uranium, thorium, and radium. The plutonium concentrations were at background levels and attributable to worldwide fallout. Cesium-137 was found in two of the three whole soil samples as levels attributable to fallout. Cs-137 and cobalt-60 were detected in trace amounts above background in the -200-mesh fractions of all three samples. These are the result of cross contamination from a previous project. The ratio of cesium to cobalt strongly indicates this contamination source, which is being further investigated and eliminated. Therefore, plutonium, cesium, and cobalt values are not reported in Table 2-1. The radionuclide distribution in the soil fractions analyzed are typical with less than 2.5 pCi/g of any isotope of uranium, thorium, and radium.

The primary objective of this study was to determine the type and nature of radionuclides in the soil samples and the likely source of the radionuclides. Since the results described above indicates only the presence of radionuclides that occur naturally and in concentrations indicative of background, the data do not indicate that their presence is of anthropogenic origin. Another approach to answering the question of radionuclide artifacts is to determine the relative concentration of radioisotopes in the naturally occurring uranium-238 and thorium-232 decay chains. Table 4-1 and Figure 4-2 show the concentration of uranium-238 and two of its daughters, thorium-230, and radium-226, in each of the three soil samples. These three radionuclides are in equilibrium within experimental error of the analytical procedures, indicating that no radionuclide has been enriched or depleted by either artificial or natural means. The same comments can be made for the naturally occurring radionuclides measured in the thorium-232 chain, namely thorium-232, radium-228, and thorium-228

PARTICLE SIZE DISTRIBUTIONS

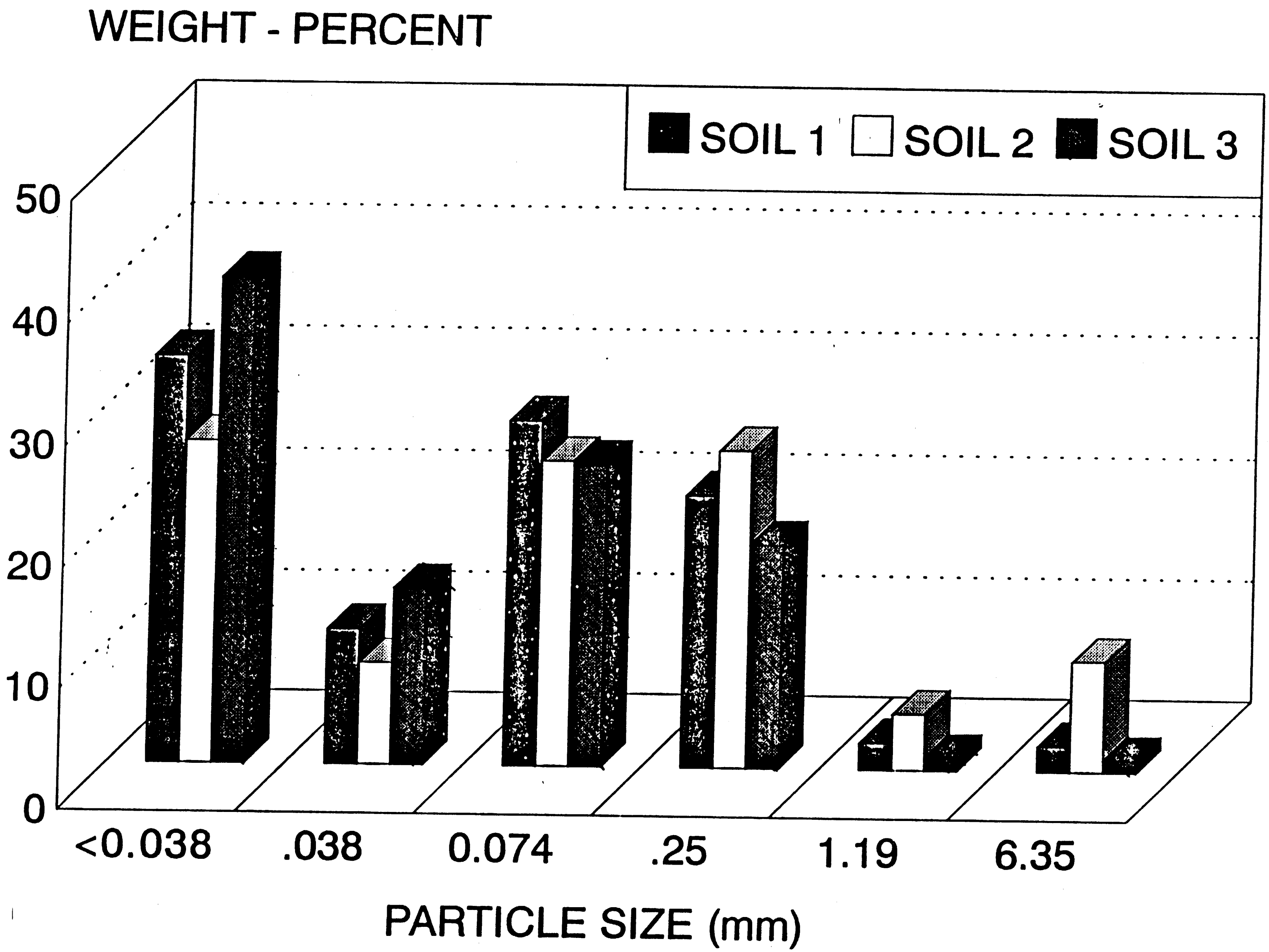

Figure 4-1

EQUILIBRIUM OF RADIONUCLIDES
Uranium Series

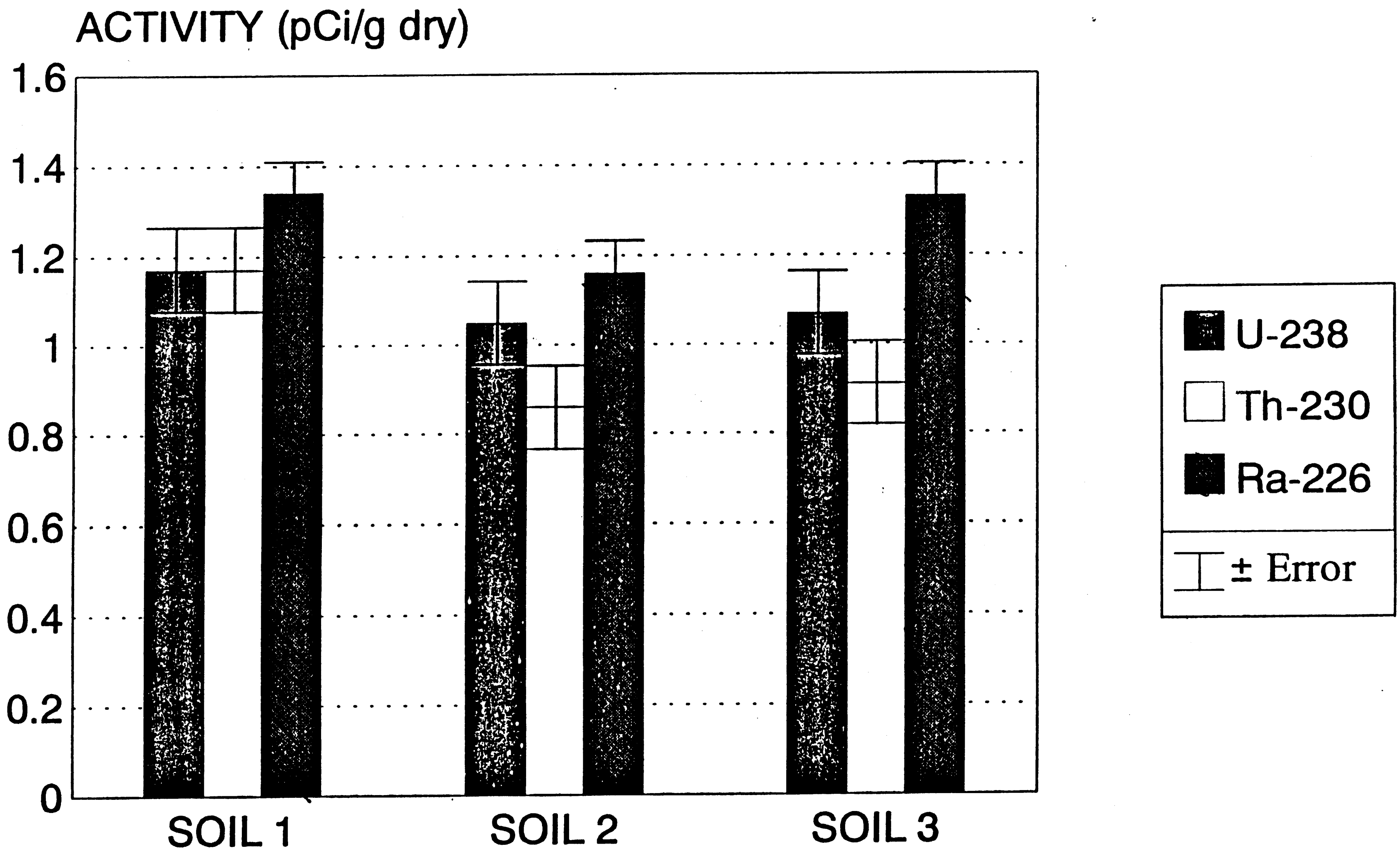

Figure 4-2

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EQUILIBRIUM OF RADIONUCLIDES
Thorium Series

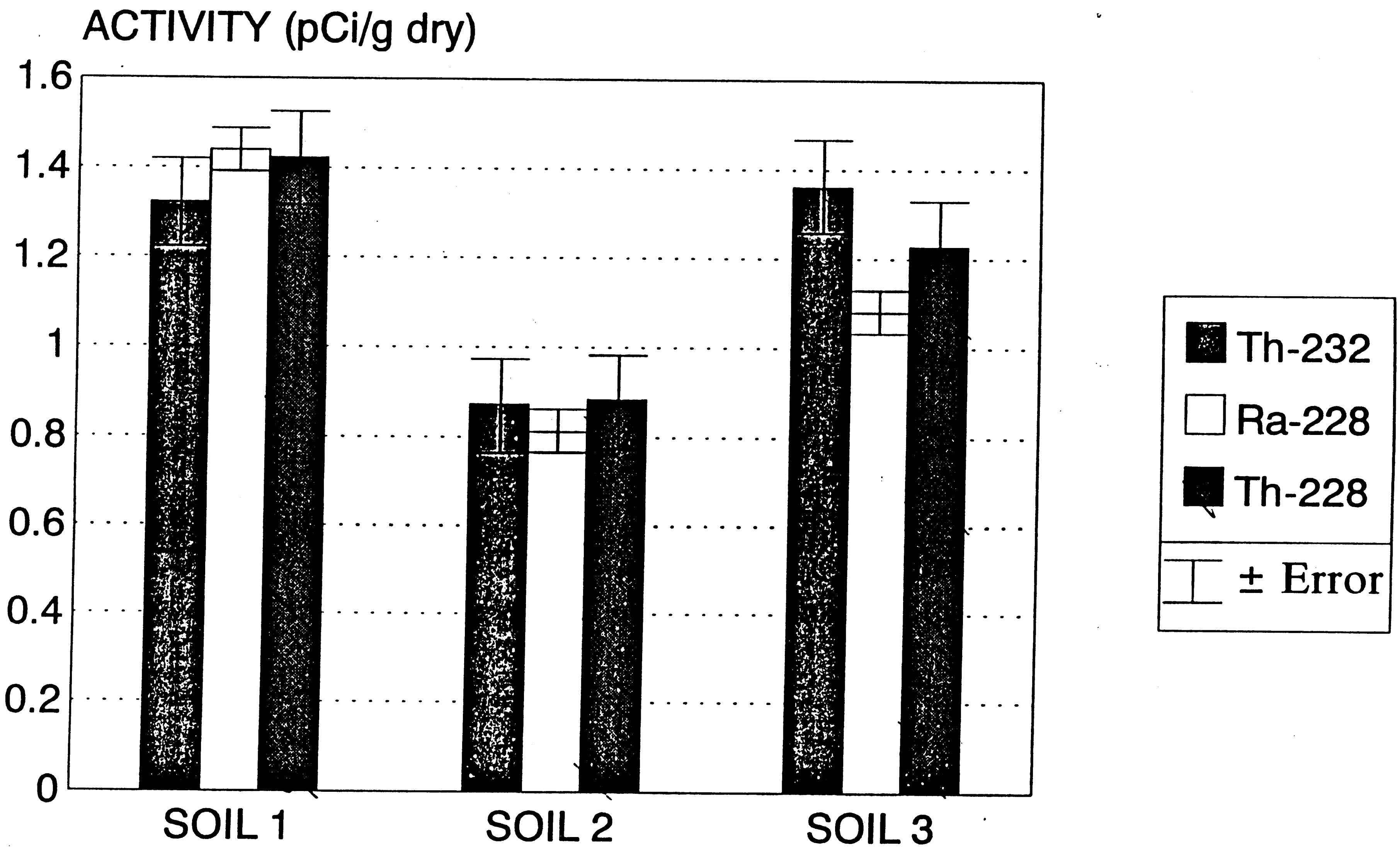

Figure 4-3

(Table 4-2 and Figure 4-3). Considering the background concentrations of these radionuclides, the results indicate that these radionuclides are naturally occurring and present at concentrations within the range of natural background.

4.3 Petrographic Examination

Petrographic analysis of all materials greater than 400 mesh (0.038 mm), reveals naturally occurring rock particles and minerals with only trace amounts of anthropogenic materials (Table 3-1). There are no apparent anthropogenic radium artifacts from naval ships such as those reported from the nearby Hunters Point waste disposal site (DEA94). The radioactivity appears to be predominantly from naturally occurring minerals in the soil and is concentrated in the heavy mineral fractions.

The naturally occurring radioactive minerals are from a granitic rock source found concentrated in the heavy mineral fractions (greater than 2.89 specific gravity) of all three samples (Table 3-1). The heavy minerals are most abundant in the medium to fine sand-size fractions, -60/+200-mesh (-0.250/+0.075-mm), where they comprise from ⅓ to ½ of the weight percent of these size fractions (Table 3-2). The silt-size fraction, -200/+400-mesh (-0.075/+0.038-mm), contain up to 10 percent heavy minerals. The radioactive minerals are readily apparent in the statistical point count of the heavy mineral species made with the optical petrographic microscope (Table 3-2).

The heavy-mineral fractions contain monazite and zircon as the major source of radioactivity, possibly with a very minor source from the opaque heavy fraction containing slag and other materials. These materials are depicted in the photomicrographs (Plates C-I) and will be discussed and correlated below with the radiochemical measurements made on the heavy mineral fractions of the three samples.

Monazite is a rare earth, thorium orthophosphate, and the chief ore mineral of thorium. The monazite has a specific gravity between 4.7 and 5.5 g/cc and occurs as subrounded, hard, dense, smooth surfaced particles with greatest abundance in the -60/+200-mesh (-0.250/+0.075-mm) fraction. Some of these particles are depicted in Plates D-H. The average amount of monazite in this size range for Soil 1, 2, and 3 is 7, 6, and 6 percent, respectively (Table 3-2). The measured thorium-232 concentration in the heavy mineral fractions of the three samples is 4.98, 3.54, and 3.17 pCi/g, respectively. The amount of thorium oxide in the monazite of the eastern United States varies between 3 and 10 percent, while uranium is approximately 10 percent of the thorium by weight (MER71). In general, the thorium-232 that was measured in the size fractions described above appears to correlate with the abundance of monazite (Table 3-2). Moreover, it is also apparent from the comparison of the thorium-232 concentration of the sand-size fraction and corresponding heavy-mineral fraction that the thorium-232 is contained entirely in the heavy mineral fraction.

Zircon is a zirconium silicate with up to 4 percent substitution of either thorium or uranium for zirconium. The zircon has a specific gravity between 3.9 and 4.8 g/cc and occurs as tetragonal crystals to subrounded particles more abundantly in the fine sand-size, -100/+200-mesh (-0.150/+0.075-mm) fraction, as depicted in Plates D-H. The average zircon ranges between 10 to 15 percent of the heavy mineral fraction in this size range (Table 3-2). The uranium-238 concentration for the -60/+400-mesh (-0.250/+0.038-mm) fraction in Soil 1, 2, and 3 is 5.22, 4.64, and 4.24 pCi/g, respectively. The measurements of uranium-238 and its daughter, thorium-230, reflect the zircon and lesser contribution from monazite in the heavy mineral fractions of Soil Samples 1 to 3. Again, it is apparent that the concentration of these radionuclides is contained in the heavy mineral fraction and correlates largely with the zircon.

The opaque minerals comprise from 16 to 51 percent of the heavy mineral fractions (Table 3-2). Some of these materials are heavy slag or cinders, depicted in Plate C. Some trace amounts of other anthropogenic opaque or amorphous materials are also depicted in Plate I. These materials constitute candidate materials for very low levels of radiation. The affiliation of uraninite in coal slag or cinders as a contributing source of radioactivity has been cited for a Superfund site (NEI89). However, the potential for radioactivity from this source in these samples is negligible.

The fines passing the 400-mesh (0.038-mm) sieve were not tested for mineral content. However, this material contains radioactivity in measurable amounts, although it is background levels (Table 2-1). This is probably from adsorption of radioactive cations on clay particles or from finer size fragments of the naturally occurring zircon or monazite, as seen in other studies conducted at NAREL (NEI89).

5.0 Conclusions

Three soil samples from the Hunter's Point Annex, Parcel B, were received at NAREL for examination to determine the radionuclide content, the particle-size and radionuclide distribution of the samples, and perform a preliminary petrographic examination, including heavy-mineral separation. The primary objective of this study was to determine the nature of radionuclides in the soil samples and the likely source of the radionuclides. The particle-size distribution of Soils 1, 2, and 3 are very similar (Table 1-1). Approximately half the material is in the -16/+200-mesh (1.19 to 0.074 mm) fractions. Much of the remaining material is in the -400-mesh (<0.038-mm) fraction. Only a small percentage is found in the +16-mesh (1.19-mm) fractions. Each whole soil sample contains only background quantities of uranium, thorium, and radium (Table 2-1). The radionuclide distribution in the soil fractions analyzed are typical with less than 2.5 pCi/g of any isotope of uranium, thorium, and radium.

Uranium-238, thorium-230, and radium-226 are in equilibrium as are thorium-232, radium-228, and thorium-228, indicating that no radionuclide has been enriched or depleted by either artificial or natural means (Table 4-1 and 4-2). Considering the background concentrations of these radionuclides, the results indicate that these radionuclides are due to natural sources.

Petrographic examination of the minerals in the three soil samples indicates that the radioactivity is from naturally occurring monazite and zircon (Table 3-1 and 3-2). Very minor amounts may be associated with cinder/slag material.

6.0 References

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APPENDIX A

Tables

TABLE 1-1
PARTICLE-SIZE DISTRIBUTIONS FOR SOIL 1, 2, AND 3

SOIL 1 PARTICLE-SIZE DISTRIBUTION	
Fraction (mm)	Weight Percent (%)
+6.35	2.11
-6.35/+1.19	2.22
-1.19/+0.25	22.49
-0.25/+0.074	28.47
-0.074/+0.038	11.18
-0.038	33.53
SOIL 2 PARTICLE-SIZE DISTRIBUTION	
Fraction (mm)	Weight Percent (%)
+6.35	9.07
-6.35/+1.19	4.60
-1.19/+0.25	26.18
-0.25/+0.074	25.17
-0.074/+0.038	8.38
-0.038	26.60
SOIL 3 PARTICLE-SIZE DISTRIBUTION	
Fraction (mm)	Weight Percent (%)
+6.35	0.99
-6.35/+1.19	1.00
-1.19/+0.25	18.49
-0.25/+0.074	24.90
-0.074/+0.038	14.62
-0.038	40.00

TABLE 2-1
RADIONUCLIDE DISTRIBUTIONS FOR SOIL 1, 2, AND 3[(1), (2), (3)]

SOIL 1 RADIONUCLIDE DISTRIBUTION

Fraction (mm)	Uranium			Thorium				Radium[(4)]	
	233/234	235	238	227	228	230	232	226	228
Whole	1.45 ± 0.133	0.060 ± 0.022	1.17 ± 0.115	0.11 ± 0.039	1.42 ± 0.107	1.17 ± 0.0919	1.32 ± 0.0991	1.34 ± 0.0665	1.44 ± 0.0435
-6.35/+0.25	0.91 ± 0.10	0.038 ± 0.018	0.82 ± 0.097	0.14 ± 0.050	0.65 ± 0.081	0.82 ± 0.086	0.56 ± 0.070	0.750 ± 0.0560	0.495 ± 0.0427
-0.25/+0.038	1.77 ± 0.173	0.10 ± 0.033	1.71 ± 0.168	0.34 ± 0.084	1.60 ± 0.139	1.74 ± 0.141	1.52 ± 0.130	1.90 ± 0.0793	1.62 ± 0.104
-0.038	1.15 ± 0.108	0.058 ± 0.021	0.98 ± 0.098	0.12 ± 0.065	2.3 ± 0.24	1.9 ± 0.21	2.2 ± 0.22	1.61 ± 0.0717	1.88 ± 0.0459

SOIL 2 RADIONUCLIDE DISTRIBUTION

Fraction (mm)	Uranium			Thorium				Radium	
	233/234	235	238	227	228	230	232	226	228
Whole	1.02 ± 0.101	0.051 ± 0.019	1.05 ± 0.103	0.047 ± 0.036	0.88 ± 0.13	0.86 ± 0.11	0.87 ± 0.11	1.16 ± 0.0638	0.810 ± 0.0290
-6.35/+0.25	0.66 ± 0.094	0.0040 ± 0.021	0.61 ± 0.090	0.13 ± 0.047	0.56 ± 0.073	1.06 ± 0.0978	0.47 ± 0.062	0.757 ± 0.0568	0.228 ± 0.0258
-0.25/+0.038	1.6 ± 0.18	0.077 ± 0.032	1.6 ± 0.18	0.34 ± 0.083	1.50 ± 0.136	2.06 ± 0.160	1.64 ± 0.139	2.21 ± 0.0857	1.19 ± 0.1008
-0.038	1.8 ± 0.20	0.19 ± 0.052	1.6 ± 0.19	0.10 ± 0.042	1.0 ± 0.11	0.94 ± 0.099	0.92 ± 0.097	1.54 ± 0.0740	1.09 ± 0.0432

SOIL 3 RADIONUCLIDE DISTRIBUTION

Fraction (mm)	Uranium			Thorium				Radium	
	233/234	235	238	227	228	230	232	226	228
Whole	1.11 ± 0.107	0.0605 ± 0.021	1.07 ± 0.105	0.083 ± 0.034	1.23 ± 0.0999	0.905 ± 0.0801	1.36 ± 0.102	1.33 ± 0.0667	1.06 ± 0.0372
-6.35/+0.25	0.87 ± 0.12	0.051 ± 0.026	0.97 ± 0.12	0.10 ± 0.039	0.46 ± 0.064	0.782 ± 0.0782	0.42 ± 0.056	0.808 ± 0.0548	0.398 ± 0.0410
-0.25/+0.038	2.68 ± 0.258	0.089 ± 0.035	2.45 ± 0.241	0.42 ± 0.088	2.18 ± 0.160	2.39 ± 0.165	2.41 ± 0.166	2.49 ± 0.0893	1.13 ± 0.0784
-0.038	1.09 ± 0.107	0.039 ± 0.018	1.09 ± 0.108	0.12 ± 0.054	1.4 ± 0.14	1.3 ± 0.14	1.3 ± 0.14	1.74 ± 0.0799	1.60 ± 0.0515

(1) Units for each isotope are pCi/g ash ± pCi/g ash except for Ra-228, which is pCi/g dry ± pCi/g dry.
(2) The uncertainty represents the 2-sigma counting error.
(3) The radium-226 values are from the deemanation analysis, the radium-228 values are from gamma spectroscopic analysis.

TABLE 3-1 MINERAL COMPOSITION OF SOIL FRACTIONS IN SOIL SAMPLES 1, 2, AND 3

SOIL SAMPLE 1 - PERCENT MINERAL COMPOSITION							
Sieve Size (mm)	+6.35	-6.35/+1.19	-1.19/+0.25	-0.25/+0.149	-0.149/+0.074	-0.074/+0.038	
Serpentinite(1)	60	35	—	—	—	—	
Granitic Rock	40	42	2	—	—	—	
Sandstone	—	10	—	—	—	—	
Quartzite	—	2	3	3	5	3	
Quartz	—	—	76	43	41	65	
Feldspar	—	—	10	12	20	23	
Heavy Minerals(2)	—	1	5	40	34	9	
Asbestos	—	1	1	1	T	T	
Other(3)	—	9	3	1	T	T	
SOIL SAMPLE 2 - PERCENT MINERAL COMPOSITION							
Sieve Size	+6.35	-6.35/+1.19	-1.19/+0.59	-0.59/+0.25	-0.25/+0.149	-0.149/+0.074	-0.074/+0.038
Highly Weathered Rock(1)	20	2	2	—	—	—	—
Granitic Rock	74	80	18	8	1	—	—
Sandstone	3	5	5	2	2	5	5
Quartz	—	—	55	65	31	32	65
Feldspar	—	—	—	20	20	18	20
Heavy Minerals(2)	—	—	2	5	45	45	10
Asbestos	—	—	T	T	T	T	—
Other(3)	3	8	13	T	1	T	—
SOIL SAMPLE 3 - PERCENT MINERAL COMPOSITION							
Sieve Size (mm)	+6.35	-6.35/+1.19	-1.19/+0.297	-0.33/+0.25	-0.25/+0.13	-0.13/+0.074	-0.074/+0.038
Highly Weathered Rock(1)	10	10	1	—	—	—	—
Granitic Rock	70	50	2	—	—	—	—
Sandstone	—	20	5	2	—	—	—
Quartzite	—	4	3	3	4	3	T
Quartz	—	—	66	73	47	43	74
Feldspar	—	—	15	16	15	14	20
Heavy Minerals(2)	—	1	5	5	34	40	6
Asbestos	—	—	T	T	T	—	—
Other(3)	20	15	3	1	T	T	T

T = Trace amount (0.1 to 0.5%)
— = None reported

(1) Soft serpentinite contains veins/bands of asbestos. Highly weathered rock particles in soil samples numbers 2 and 3 are predominately granitic with minor amounts of serpentinite.

(2) Heavy minerals are materials greater than 2.89 specific gravity.

(3) Other particles include, in order of abundance, cinders/slag, wood/plant particles, glass, and amorphous anthropogenic materials.

TABLE 3-2 HEAVY MINERAL COMPOSITION OF SOIL FRACTIONS FROM SOIL SAMPLES 1, 2, AND 3.

SOIL SAMPLE 1 - PERCENT HEAVY MINERAL COMPOSITION			
Sieve Size (mm)	-0.25/+0.13	-0.13/+0.074	-0.074/+0.038
Weight % Heavy Mineral	34	40	9
Opaque Minerals(1)	22	38	51
Hornblende	38	25	32
Hypersthene	21	10	6
Epidote	9	3	5
Garnet	3	3	1
Zircon	T	15	4
Monazite	6	5	1
Other(2)	1	1	T
SOIL SAMPLE 2 - PERCENT HEAVY MINERAL COMPOSITION			
Sieve Size (mm)	-0.25/+0.13	-0.13/+0.074	-0.074/+0.038
Weight % Heavy Mineral	45	45	10
Opaque Minerals(1)	26	40	32
Hornblende	29	27	31
Hypersthene	14	6	12
Epidote	10	7	12
Garnet	8	3	3
Zircon	1	10	9
Monazite	9	6	1
Other(2)	3	1	T
SOIL SAMPLE 3 - PERCENT HEAVY MINERAL COMPOSITION			
Sieve Size (mm)	-.025/+0.13	-0.13/+0.074	-0.074/+0.038
Weight % Heavy Mineral	34	40	6
Opaque Minerals(1)	16	30	40
Hornblende	38	37	35
Hypersthene	15	4	5
Epidote	16	10	8
Garnet	6	3	1
Zircon	T	10	9
Monazite	8	5	T
Other(2)	1	1	2

T - Trace Amount (0.1 - 0.5%)

(1) Opaque minerals include magnetite, ilmenite, slag, and minor other.

(2) Other heavy minerals include rutile, tourmaline, staurolite, and very minor other materials.

TABLE 4-1
SOIL RADIONUCLIDE CONCENTRATION OF URANIUM-238
AND SELECT DAUGHTERS

Soil	U-238 (pCi/g ash)	Th-230 (pCi/g ash)	Ra-226 (pCi/g ash)
1	1.17 ± 0.115	1.17 ± 0.0919	1.34 ± 0.0665
2	1.05 ± 0.103	0.86 ± 0.11	1.16 ± 0.0638
3	1.07 ± 0.105	0.905 ± 0.0801	1.33 ± 0.0667

TABLE 4-2
SOIL RADIONUCLIDE CONCENTRATION OF THORIUM-232
AND SELECT DAUGHTERS

Soil	Th-232 (pCi/g ash)	Ra-228[1] (pCi/g dry)	Th-228 (pCi/g ash)
1	1.32 ± 0.0991	1.44 ± 0.0436	1.42 ± 0.107
2	0.87 ± 0.11	0.812 ± 0.0295	0.88 ± 0.13
3	1.36 ± 0.102	1.08 ± 0.0376	1.23 ± 0.0999

(1) The radium-228 value reported was determined by gamma spectrometry, as the result of a high minimum detectability activity in the alpha spectrometry result.

APPENDIX B

Plates

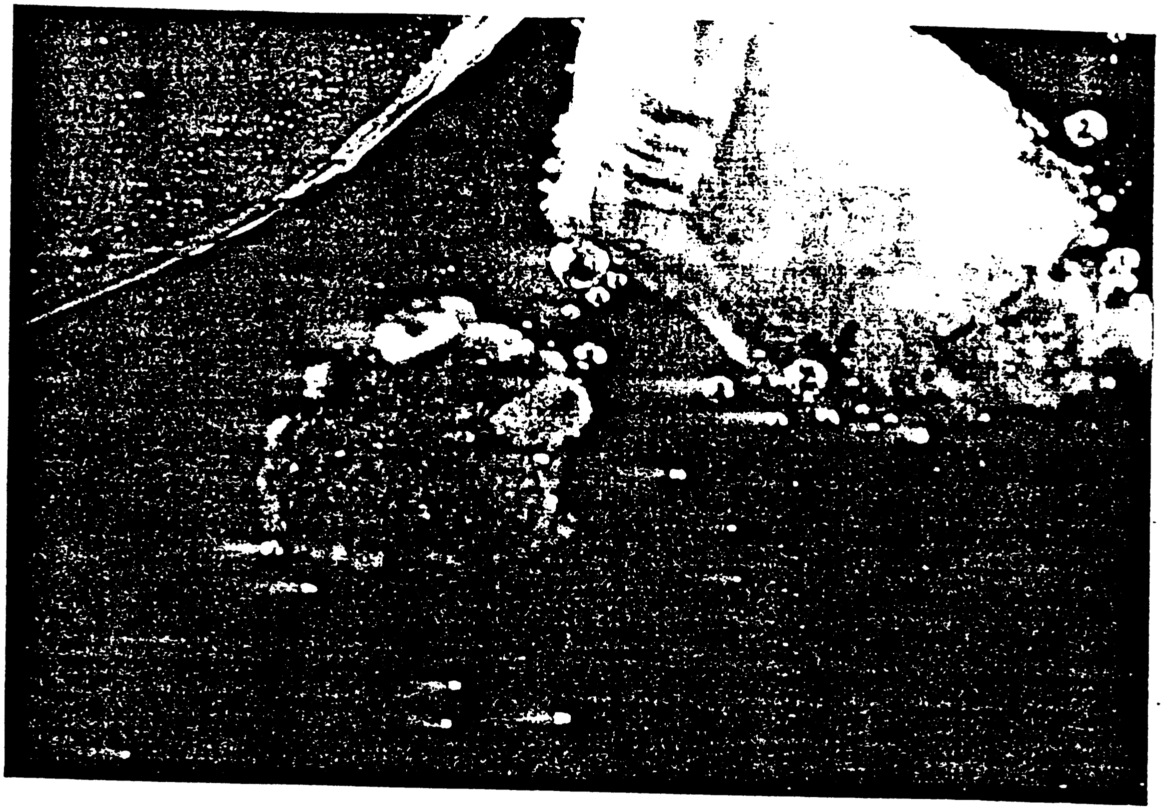


Plate A: Photomicrograph (10X, Reflected Light) of gravel-size particles of Soil 1. Serpentinite (top right) is soft and contains asbestos bands. Sandstone (bottom) particle is highly friable.

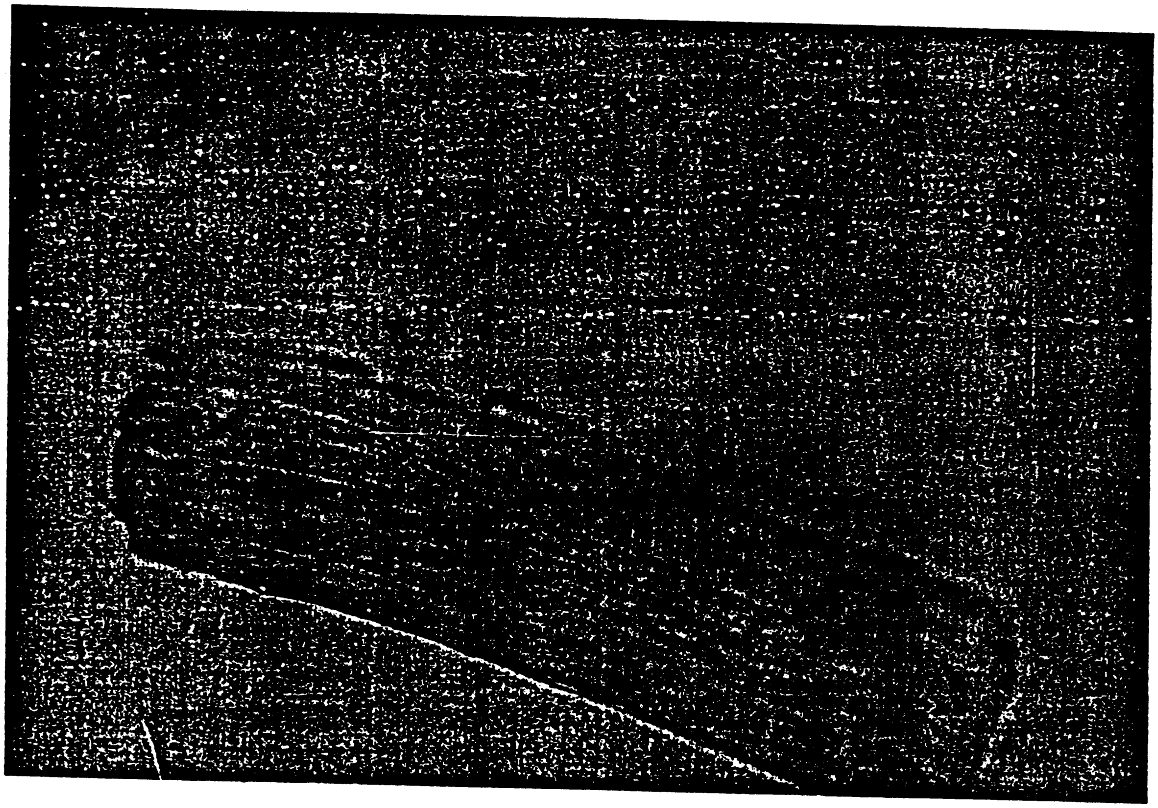


Plate B: Photomicrograph (100X, Reflected Light) of asbestos that occurs as bands in serpentinite and as free particles of sand-size fractions, Hunters Point Annex, Parcel B.

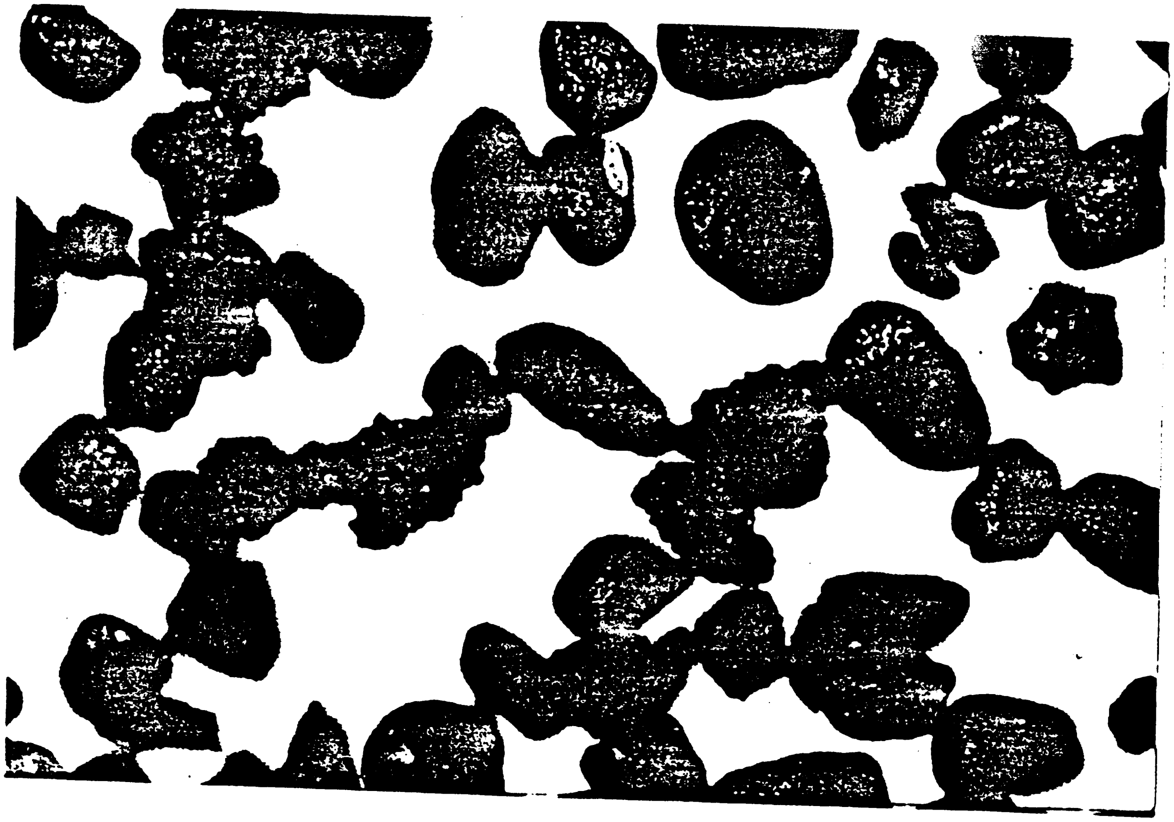


Plate C: Photomicrograph (100X, Reflected Light) of magnetic heavy fraction of the -100/+200-mesh size from Soil 2. Approximately half of this fraction consists of reddish black magnetic cinder/slag particles and the remainder black subrounded magnetite particles.

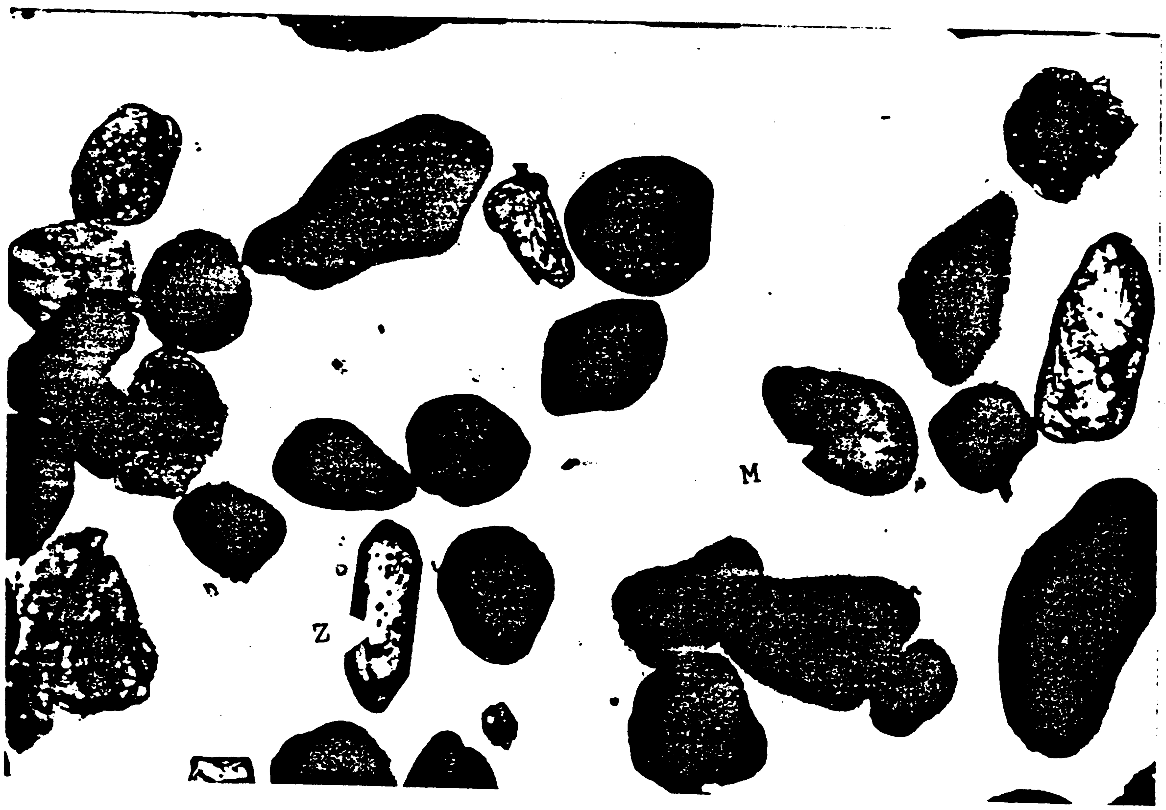


Plate D: Photomicrograph (100X, Transmitted Light) of the heavy mineral fraction of the -100/+200-mesh size of Soil 1. The radioactive minerals are monazite (M) and zircon (Z).

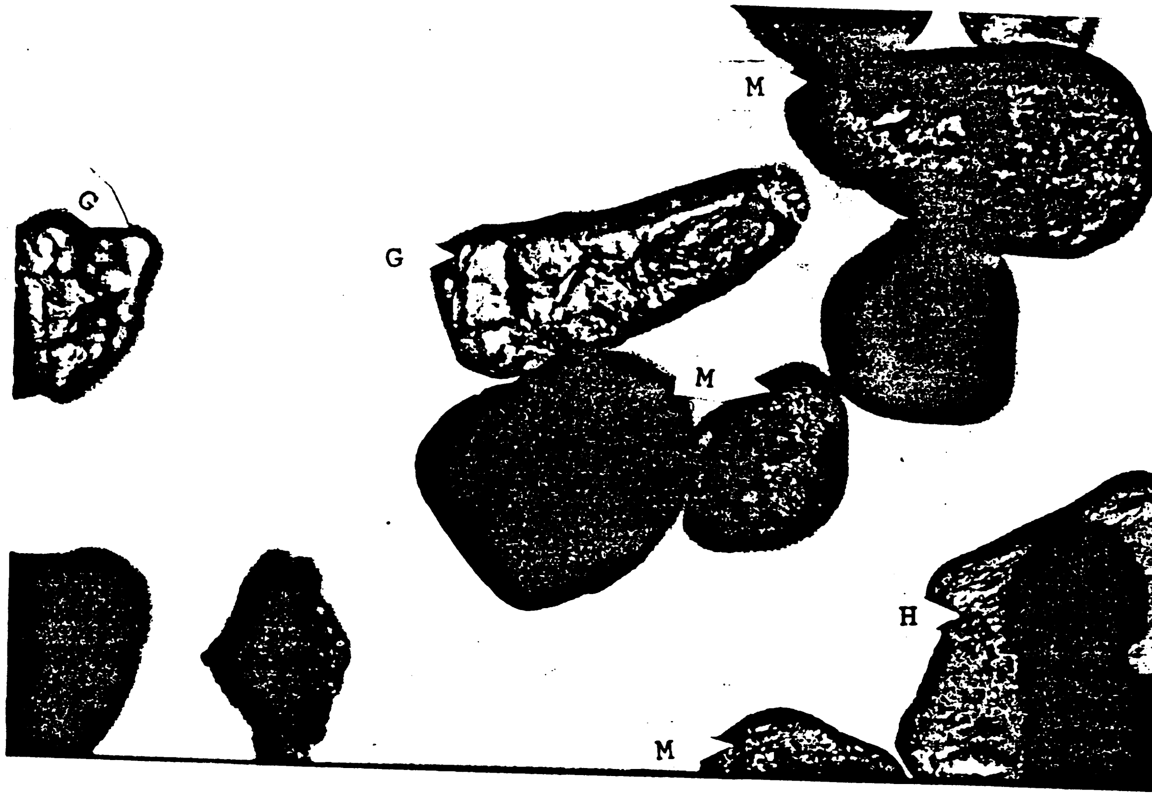


Plate E: Photomicrograph (100X, Transmitted Light) of heavy-mineral fraction of the -60/+200-mesh size of Soil 2 showing abundant monazite (M), garnet (G), and black opaque minerals; hypersthene (H) is also depicted in lower right.

Plate F: Photomicrograph (100X, Transmitted Light) of heavy-mineral fraction of the -100/+200-mesh size of Soil 2. In this size, zircon (Z) is more abundant than monazite (M) as the most abundant radioactive mineral.

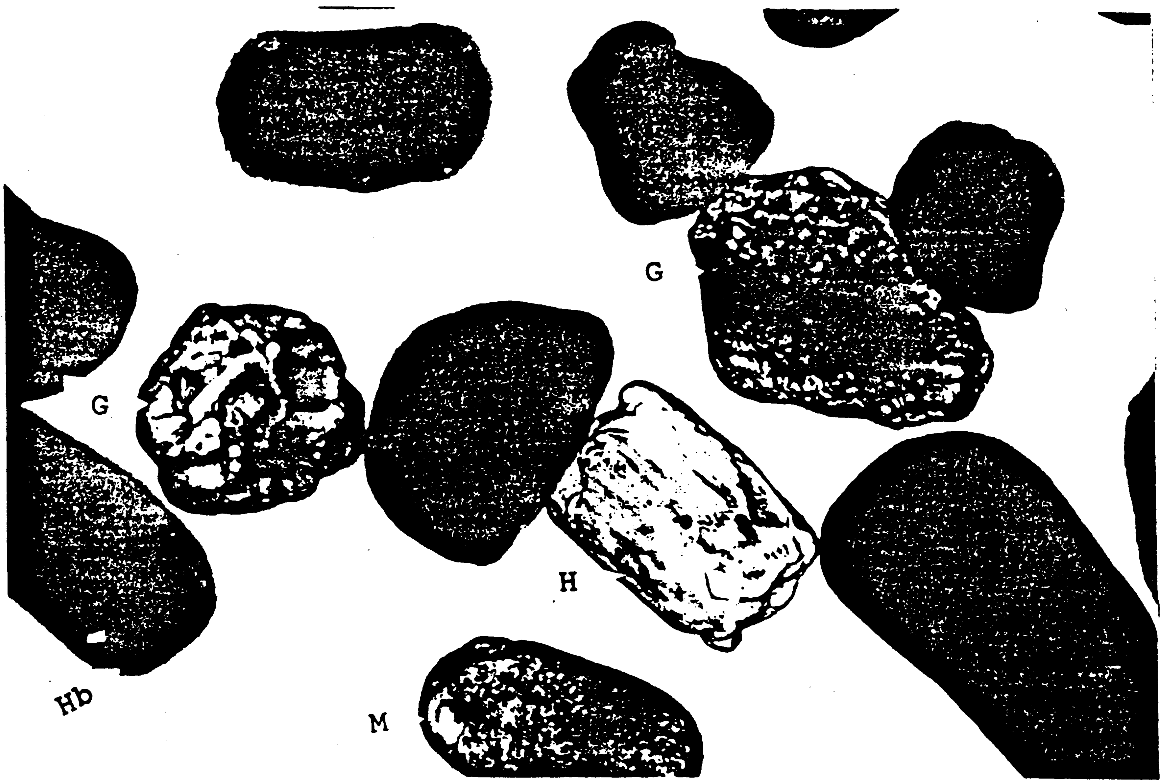
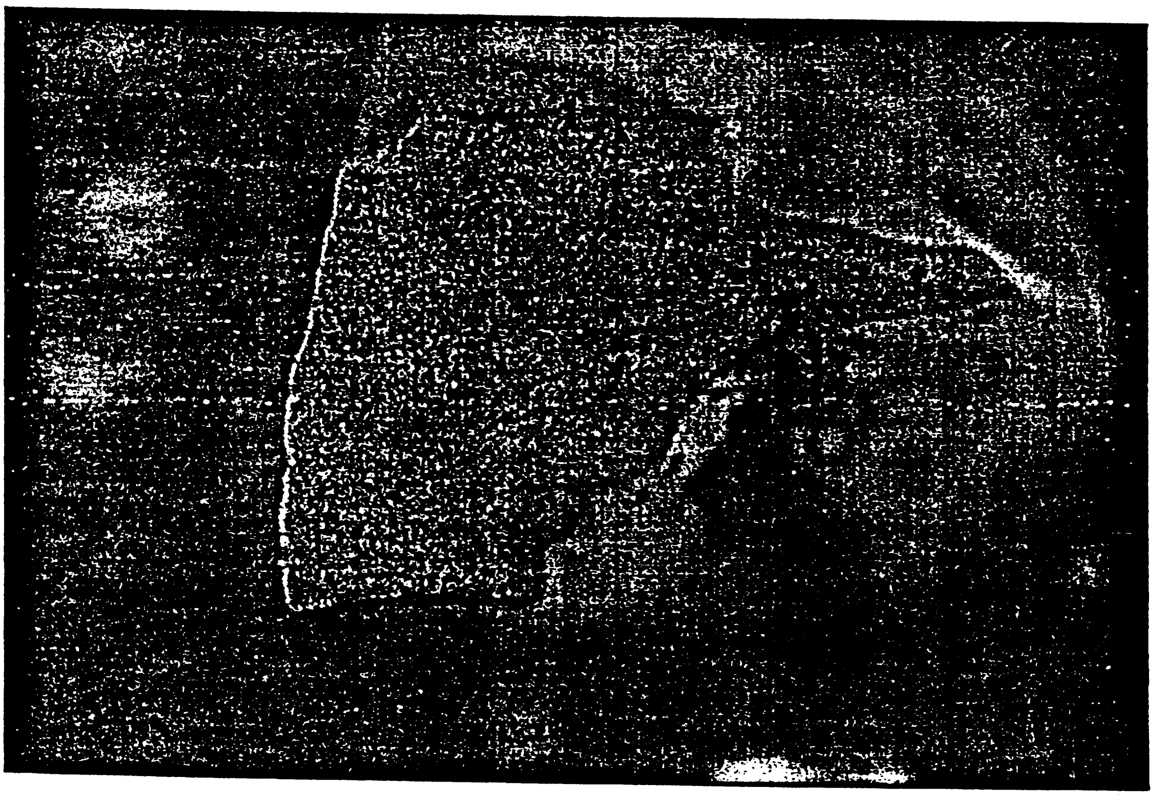


Plate G: Photomicrograph (100X, Transmitted Light) of heavy-mineral fraction of the -60/+100-mesh size of Soil 3. Monazite (M) is the most abundant radioactive mineral in this size. Other transparent heavy minerals shown are garnet (G), hypersthene (H), hornblende (Hb), and black opaques.

Plate H: Photomicrograph (100X, Transmitted Light) of heavy-mineral fraction of the -100/+200-mesh size of Soil 3. In this size fraction, zircon (Z) is more abundant than monazite (M) as the radioactive mineral. Others depicted are garnet (G), hornblende (Hb), epidote (E) and black opaque minerals.

A



B

Plate I: Photomicrographs (100X, Reflected Light) of minor amounts of anthropogenic material occurrences in Soil 2 and 3. Both are in the course sand-size fractions. The golden opaque heavy material from Soilo 2 (A above) may be a cavity filling or other material; the shape and indentations are distinctive. The blue and green amorphous material (B) from Soil 3 is possibly paint chips or other material.